SUBGRADE SUPPORT CHARACTERISTICS

APRIL 1957

No. 10

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

by

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SUBGRADE SUPPORT CHARACTERISTICS

TO: K. B. Woods, Director
Joint Highway Research Project — April 4, 1957

FROM: H. L. Michael, Assistant Director — File: 9-7

Attached is a technical paper by Messrs. R. C. Geldmacher, R. L. Anderson, J. W. Dunkin, G. R. Partridge, M. E. Harr, and L. E. Wood entitled, "Subgrade Support Characteristics."

This paper was presented at the last Annual Meeting of the Highway Research Board and is being submitted to them for publication. A review of the manuscript will be made by a technical committee of the Bureau of Public Roads prior to publication.

This report summarizes the experimental portions of the Rigid Pavement Deflection Study. It has been conducted during the past three years in cooperation with the State Highway Department and the Bureau of Public Roads. The equipment deflection portion of the project was included in a paper previously submitted to this Board. The theoretical study is planned for incorporation in a paper to be prepared at a later date.

Respectfully submitted,

Harold L. Michael/HB

Harold L. Michael, Secretary

HLM:hgb

Attachment

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TECHNICAL PAPER

SUBGRADE SUPPORT CHARACTERISTICS

by

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Joint Highway Research Project
Project C-36A
File: No. 9-7

Purdue University
Lafayette, Indiana

April 4, 1957

INTRODUCTION

In 1949 the State Highway Department of Indiana and the Bureau of Public Roads constructed an experimental road for the purpose of investigating means of preventing pavement pumping on highways that carry a high traffic volume with a normal distribution of heavy axle loads. (1)*

This project is located in the Northwest corner of Indiana on a section of US Road No. 41. The test road is entirely within the Valparaiso morainic area, and is underlain by mixtures of silt and clays deposited during the Wisconsin glacial stage.

Each mile of the project has nine subbase sections as follows: (a) two of a soil-cement mixture, one 3 and one 5-inch in thickness; (b) three of open-graded crushed stone, one each with a 3, 5 and 8 inch thickness; (c) three of dense-graded crushed stone, one each with a 3, 5 and 8 inch thickness; and (d) one section where the pavement was placed on the natural soil.

In order to determine the differences in performance of the concrete pavements on the various-subbase treatments many types of observations have been made. Among these are pavement roughness,

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* Numbers in parenthesis refer to the bibliography.

differential levels, visual inspections and moisture cell readings.(2)

Included in the original plan for the test road was a series of deflection studies to be carried on by the Joint Highway Research Project with the cooperation of the Division of Engineering Sciences of Purdue University.

This pavement deflection project was initiated in October, 1953, with the twofold purpose of developing a multi-channel instrument capable of measuring dynamic pavement deflections and of investigating the behavior of pavement-earth systems under various load conditions.

PRELIMINARY STUDIES

Pavement deflection measurements were made by means of differential transformers. The transformers were attached to the pavement and the transformer cores were connected to reference rods driven into the bottom of cylindrical holes in the earth. The relative motion between the pavement and reference rods was measured.

In the early stages of this investigation much effort was directed to the development of necessary equipment for obtaining the desired pavement deflection measurements. A major task was the design and construction of a fourteen channel recording device.* Other problems which were considered dealt with such items as: proper design of a transducer holder and calibrating device, effect of variation on the speed of the test vehicle, effect of the lateral placement of the test vehicle, effect of changes in environment, and the proper depth for the placement of reference rods. These items are

* The development of this instrument is covered in a paper which has been submitted to the American Institute of Electrical Engineers.

discussed under separate headings.

A holder was developed from which the transducer could be removed when not in use. The holder was composed of a 2-inch diameter by 7-inch long brass sleeve which was mortared to and moved with the pavement (see Figure 1). The differential transformer was placed in a hollow micrometer threaded cylinder of non-magnetic steel which screwed into the brass sleeve. One revolution of this transformer holder provided a displacement of 0.025 inches.

Reference rods were made of 1/2 inch diameter steel having one end sharpened and the other end turned to a hemispherical surface upon which the transformer core holder could rest.

The transformer core holder was made of a thin brass rod connected to a socket which fitted onto the top of the reference rod.

Installation of Transducer

Holes were made in the pavement with the Indiana State Highway Department Bureau of Tests core drilling truck and also the Purdue University Joint Highway Research Project core driller.

After the pavement was cored, a soil auger was used to make holes of varying depth in the subgrade just large enough for a 1-1/2-inch pipe casing.

Next a casing of 1-1/2-inch galvanized iron pipe was placed in the hole. The pipe length was chosen so that the top of the pipe was about 2-inches below the bottom of the pavement.

The reference rod was then driven into the subgrade. The

rod length was such that from 1 to 2-feet extended into the sub-grade below the bottom of the hole and the top of the rod came to the bottom of the pavement. The sleeve mortaring operation completed the installation. Figure 2 shows the installed sleeve and an exploded view of the core holder, transducer holder, transducer, electrical leads, and sleeve cover.

Calibrating Device

A device was developed which provided direct calibration in the field (see Figure 3). This device consisted of four principal parts: a housing which fitted to the brass sleeve imbedded in the pavement, two rotating sections which afforded a means of fixing the calibrator at a null point from which differential transformer motion relative to a core could be measured in increments of 2-1/2 thousandths of an inch, and a connecting link that was used between the transducer holder and the bottom of the internal rotating part of the calibrator. The purpose of the 2-1/2 thousandths of an inch increments on the calibrating device was to provide linearity calibration.

Initial Installations

In September, 1954, 16 transducer holders were installed in a section of the US 41 test road near Cook, Indiana. This site was in a fill section having a 5-inch dense-graded stone base beneath the Portland Cement concrete. Acting on the best information available at the time, 4-foot reference rods were used.

A series of preliminary measurements was taken on the above

mentioned site. Upon analysis of the data, the question arose as to the proper depth at which reference rods should be placed. Since the answers to this question were of primary importance to the design of the overall experiment, a theoretical and experimental study of earth motion was begun.

Exploratory observations were made by spanning the pavement with a 50-foot antenna mast supported at each end and having a differential transformer attached at its center. As a result of measurements made with this arrangement, it was discovered that the reference rod moved on the order of one-half as much as the pavement. This meant that with 4-foot reference rods absolute deflections of the pavement were not being obtained.

A series of tests designed to measure earth motion at increasing depth was made in both a cut and a fill section of Route 41. All tests made in the fill section were also repeated in the cut section. On the assumption that the load bearing characteristics of the pavement changed with environmental conditions, it was decided to provide a control rod for each series of measurements. These control rods were installed one foot from the test rods. During each test, nothing was changed in the control installation and, therefore, changes indicated by the control could be applied as corrections to the test installation. Four series of measurements were made beginning at daybreak, two in the cut section and two in the fill section. It was only possible to run one test a day, but the two tests made in the fill on two different days gave almost identical results. This was also true of the

cut section.

This series of depth of influence measurements was performed by running the test truck over the gage, and recording the deflection and reference rod length. The procedure was repeated for increasing reference rod lengths and a curve of deflection versus rod length was plotted (see Figure 4). The depth of influence appeared to be greater in the fill section.

Pilot Section Tests

As a result of the depth of influence studies, a pilot section was established just south of the original site. This pilot section consisted of 10 transducer holders installed on a line across the pavement. The reference rods used in this section were 12 feet long with the upper 10 feet free from contact with the soil.

A series of measurements was then made on the pilot section. Tests were made for five lateral vehicle positions and five vehicle speeds: creep, 5, 10, 20, and 30 miles per hour. In addition, in order to determine the effect of variability in vehicle speed and lateral position, one vehicle made 30 consecutive runs in the same position and at the same speed. This series of measurements consisted of over 2,250 individual records.

Effect of Environment

A series of preliminary measurements were also made to determine how the load bearing characteristics of the pavement changed with environmental changes. For this purpose, a transducer was installed in the center of the driving lane and a test truck passed over the transducer at creep speed at 15 minute intervals. During the period of the test from 10 A.M. to 2 P.M., it was observed that the pavement deflection with this same load increased steadily until it was finally approximately 2-1/2 times as great as the original deflection. It was also observed that during this period, the center of the pavement was continually moving upward.

Deflection Profiles

The transverse deflection profiles of the pilot section for each lateral vehicle position at creep speed is shown in Figure 5. Truck 105_1 and 105_2 are the same vehicle, however, the curve labeled truck 105_1 was obtained from a seating run made preliminary to the runs of trucks 104, 103 and 105_2. The weights of the vehicles are given in Table I. The positions of the transducers and the lateral vehicle positions are given in Figure 6.

Linearity of Pavement Earth System

As previously noted, Table 1 gives the load at each wheel of each vehicle. Loads were arranged so that each vehicle, as nearly as possible, had the same front wheel load. As a result, the deformation of the pavement at a point beneath the rear wheels of all vehicles had equal components contributed by the front wheels (all vehicles had the same wheel base). As it later developed, this arrangement did not effect the results in any appreciable way since analysis of records showed the contribution of the front wheels to be quite small and any small differences in front wheel loading appeared as higher order differences at the rear wheels.

All vehicles made four passes at creep speed at each of the five lateral positions. Figure 7 shows a representative plot of the maximum deflections at each transducer location for the three test vehicles at lateral position B.

On the basis of the information gained it has been concluded that over the range of loadings used and under the conditions that the measurements were made, the pavement-earth system behaves quite linearly.

Effect of Changes in Vehicle Position

One of the factors contributing to the variance of measurements in the field was control over vehicle lateral position. As a consequence, part of the series of measurements made on the pilot section was planned to provide an estimate of the effect on pavement deflection of a small change in the lateral placement of a vehicle.

These measurements were made on the deflections at each of the ten transducers as vehicle 105 passed four times at creep speed over each of the five chosen load paths.

The maximum deflections at each transducer position were taken from the records and were plotted in a manner indicating the rate of change of deflection with respect to lateral displacement. Typical curves are shown in Figure 8.

Some care should be used in interpreting these measurements since, (1) each measured deflection resulted from simultaneous loads at two lateral placements (the two sets of adjacent wheels), and (2) the increment of lateral placement was 3.55 feet. The first condition would probably tend to reduce the rate of change of deflection with respect to lateral displacement at points located between the wheels (between points of application of loads). The second condition leaves the curves undefined between points of load application.

As might be expected, the greatest rate of change of deflection with respect to lateral position occurred at the edges of

the pavement. The rate of change at the center of the pavement (where the driving and passing lanes joined) should also be large because of the relatively small amount of load transfer from one section to the other, however a quantitative estimate was not inferred from the data because the vehicle when in position C straddled the center line and consequently the loading of the passing and driving lanes was not symmetrical.

To control the variance in deflection at the edge of the pavement (when a vehicle is near the edge) to within $\pm$ 1%, the position of the vehicle must be controlled to stay within $\pm$ .4 inches of the prescribed path. This restriction applies to a vehicle traveling at creep speed along the edge of the pavement. Corresponding restrictions at the other positions in the pavement when a vehicle is traveling at creep speed are not as stringent.

Since control over lateral vehicle placement becomes more difficult at increased speeds one would expect this factor to produce a larger component of variance in measurements made at higher speeds. Measurements made at higher speeds show this to be true.

Because the pavement-earth system behaves as a linear elastic system it is possible to devise an experiment that will take advantage of this property in such a way that an equivalent single wheel load along with closely spaced increments of lateral displacement may be obtained. All that is necessary to accomplish this is to provide vehicle paths such that by algebraically

superposing deflections a resultant deflection is obtained which is equivalent to that caused by the load at one wheel. Such a procedure would enable one to obtain a more accurate representation of the effect of changes in lateral placement. This principal was used to obtain an equivalent uniformly distributed transverse load for the earth motion study which will be discussed in a later section.

Effect of Changes in Vehicle Speed

A part of the series of tests on the pilot section was made in order to obtain an estimate of the component of variance contributable to changes in speed and to provide information useful in designing a full scale experiment for more carefully exploring the relationship between vehicle speed and pavement deflection.

The runs consisted, in addition to seating runs, of three passes by the test truck at speeds of creep, 5, 10, 20, and 30 miles per hour at placement A on the pilot section.

Representative results from the pilot section are plotted in Figure 9.

An attempt was made to minimize the effect of environmental changes upon the measurements made at the pilot section by making the runs at the five different speeds within a period of fifteen minutes.

Effect of Changes in Environment

A part of the series of tests on the pilot section was designed to provide information relative to the effect of environmental changes on pavement deflection.

It is well known that a concrete pavement will warp when the temperature of its surface changes. Consequently, if a load is repeatedly passed over a given path of the pavement one might expect the deflection at a particular point to change if the environment of the pavement changed. In order to explore this problem, measurements over a period of three hours were made at each transducer position of the pilot section for all lateral positions of the three test loads. Points representing maximum deflection at vehicle position A have been taken as representative and are shown on Figure 10.

Attention should be called to the fact that each point represents one observation and is therefore not necessarily representative of the mean. However, the standard error for large samples of measurements of this sort has been found to be on the order of 1% of the mean.

The effect of changes in environment can be summarized as follows: (1) The load carrying characteristics of the pavement-earth system changed appreciably as a result of changes in environment. (2) There is some evidence that the system remained fairly linear over the load range used even though a change occurred in the amount of deflection caused by a particular load. (3) Not enough is yet known about the relationship between initial conditions of the pavement system

(condition of warping), and deflection due to moving loads to be able to accurately predict magnitudes of deflection.

If it can be shown that the pavement-earth system behaves linearly at any arbitrarily chosen time, an accurate statistical description of the boundary conditions may perhaps lead to a somewhat general solution of the problem of performance prediction and comparison. Such a statistical description of the boundary conditions would undoubtedly require a well planned series of measurements made over a period of several months.

It should be observed that, in addition to the cyclic changes in the system, long term changes are also taking place - the pavement cracks, pumping action takes place, and the modulus of elasticity may change. All these things contribute a non-stationary component which complicates the use of statistical methods. However, it may be that over periods of a year or less the non-stationary component will not be noticeable.

ADDITIONAL DEPTH OF INFLUENCE STUDIES

The proper depth for placement of the reference rods was considered to be of such basic nature that further time and effort were devoted to this subject before the evaluation of the subbase type was initiated. These additional studies were carried out at two different sites. This work is covered in following sections.

At the same time the experimental work was being carried out in the field, a theoretical study was begun to evaluate earth motion beneath a loaded pavement. Some basic assumptions of the study were to consider the earth as a semi-infinite, homogeneous, isotropic, elastic medium whose upper surface is displaced in the form of an infinitely long trench having a profile with a specified form. A comparison between theoretical results and experimental results is presented in Figure 11. Possible reasons for the discrepancies between theory and experiment are in the assumption of a homogeneous, isotropic and elastic medium and also in the selection of boundary conditions. These assumptions are more idealized than the conditions that actually exist.

As an addition to the knowledge gained in tests at Cook, Indiana, another depth of influence experiment was made at the Purdue University Airport during December, 1955. In this experiment simultaneous measurements of the relative motion between the pavement and five specified depths were made. A row of five differential transformers with one foot between centers was installed in the middle of a 45' 10" by 13' 9" concrete slab. Reference rods for transducers were anchored at depths

of 3,6,10,15, and 19 feet below the top of the pavement. Eight test lanes were laid out so that the lateral position of the test truck could be controlled.

Two types of tests were performed. One set of fifteen identical runs was made to determine the variability of the complete sensing and measuring system. In the other test one run was made in each of the test lanes at the same speed. Because of the way the test lanes were chosen, the wheel positions, considering all eight runs, were almost uniformly spaced and, hence, represented a close approximation to a line load. The purpose of this was to give a boundary condition on the top of the earth under the pavement that would be similar to the one assumed in the theoretical development.

In an attempt to further improve on the depth of influence tests, a series of measurements was made on a pavement slab on US 52 about 1/2-mile west of Klondike, Indiana during June, 1956.

The improvements were as follows:

(1) A slab was selected in a cut section in the hope of attaining a fairly homogeneous subgrade; (2) By using the power driven soil auger it was possible to auger to about 43 feet below the pavement.

Six transducers on one foot centers were installed on the center line of the driving lane. These transducers were also centered in the direction of the length of the slab. The free length of the reference rods were 1'-10", 5'-4", 9'-5", 14'-11", 27'-0", and 42'-7".

Depth of influence curves for the Purdue Airport, US 52, US 41 and the theoretical problem are shown in Figure 11. The experimental

curves can not be directly compared since they involved different pavements and, of course, different subgrades. However, they exhibit the same general shape.

GENERAL EXPERIMENTAL PROCEDURE

As was previously noted, each mile of the US 41 test road was divided into nine sections with each section having either a different foundation treatment or a varying depth of subbase.

The concrete pavement for the entire project was 24 feet wide, 9 inches thick at each edge and 8 inches thick at the center. The test sections were reinforced with 45 pounds of mesh per 100 square feet and contained contraction joints spaced at 40-foot intervals with load transfers one foot on centers.

Comparison of Nine Subgrade Treatments

Three slabs from each of the nine sections of one mile of the Test Road were chosen to be tested. In an effort to select slabs as nearly identical as possible it developed that the three slabs were usually not adjacent. Factors which prevented choosing adjacent slabs were as follows:

(a) Slabs with appreciable differences in location of transverse cracks were not used.

(b) Slabs with evidence of excessive pumping were not used.

(c) Slabs which adjoined crossovers or driveways were not used.

(d) Slabs near culverts were not used.

The locations of the test slabs, the deflection devices, and strain

gages are shown on Figure 12.

The quarter point deflection gage locations in the center of the driving lane were made 10 feet from the north joint of the slabs since this was approximately midway between the joint and the usual transverse crack in the slab. The deflection gage locations along the edge of the slabs were placed so that the center of the gage would be 3-1/2 inches from the edge of the slab. To aid in the investigation, strain gages were applied on the surfaces of the concrete section being studied.

Guide lines for the center of the left front wheel were drawn on the pavement with yellow crayon. The truck drivers with the help of guides, stationed in front of the trucks, used these lines to control lateral placement.

One line was drawn so that the center of the right rear dual assembly was 4 feet from the west edge of the pavement. This placement had been determined by previous study as the average lateral placement for this particular road.

The other line was drawn so as to get the truck as close to the edge of the pavement as possible without hitting the gages. This distance was 0.5 feet from the west edge of the pavement to the outside edge of tire tread.

For each of the above lateral placements the test trucks made a minimum of twelve passes. This number of passes was chosen on the basis of earlier work which showed that the mean deflection could be placed within a band width of ± 0.6% if the passes were sufficiently close together in time.

Since pavement warping caused the load deflection characteristics of the pavement to vary with time, a control section was established. This was quite necessary, since no more than one section could be tested on any given day. Therefore, Section 4B (see Figure 12) with 5 inches dense graded subbase, was arbitrarily chosen as the control section. At the same time that any given section was being tested, an identical test was performed on the control section. Two nearly identical trucks were used. The only difference in the trucks being a slight difference in tire size. The trucks were loaded equally with sand.

Statistical Inferences

A statistical analysis was made on the results of the tests on the nine sections.

This analysis was only possible for the center gauges located at the quarter points (see Figure 12), since the quarter points involved three slabs from each section.

A statistical analysis was not possible for edge and corner deflections and edge strain since only one slab from each section was tested and therefore the slab to slab variance was unknown.

In the analysis of the quarter points, comparisons of the ratios of test section to control section deflections (as given in Figure 13) were made for like treatments and like thicknesses. For example, 8 inches open was compared with 3 inches open and 8 inches dense but not with 3 inches dense.

As a result of this analysis, significant differences in de-

flection ratios were found between the following:

8 inches open and 3 inches open

8 inches open and 5 inches open

8 inches open and 8 inches dense

8 inches open and untreated

5 inches and 3 inches open

CONCLUSIONS

The general conclusions here are based on the pavement deflection studies and are as follows:

1. The motion of concrete pavements deflected by moving loads may be measured with a high degree of precision by means of differential transformers.
2. It is possible to provide direct calibration to the measurements of concrete pavement deflections.
3. Deflection profiles of concrete pavements may be obtained by making simultaneous measurements along a line transverse to the path of the loading vehicle.
4. Over the single rear axle load range of 4,000 to 20,000 lbs. the elastic properties of the experimental section of pavement on US Route 41 are quite linear.
5. Lack of control of lateral vehicle position can be a major contributing factor to variance of pavement deflection measurements. With the vehicle near the edge of the pavement, changes in deflection of about 1%, measured at the edge, were noted with a change of .4 inches in lateral position of the vehicle.
6. Pavement deflections decreased with increase in speed of the vehicle in the range of creep to 20 mph. This effect is also more pronounced at the pavement edge than in the center of the driving lane. For one of the conditions of load and lateral placement, as speed was increased from creep to

20 mph, a 10.8% decrease in deflection occurred at the center of the driving lane and a 23.1% decrease occurred at the edge of the pavement.

7. Earth motion beneath a load provided by a truck with 20000 pounds on dual rear axles is influenced by the soil profile. The maximum depth of influence was found to be 15 feet at the test sites on US 41 and 45 feet at one point on US 52.

8. The load carrying characteristics of the pavement-earth system change appreciably as a result of changes in environment because of pavement warping.

9. On the basis of research to date, the relationship between initial conditions of the pavement system (condition of warping), and deflection due to moving loads, is not clear and precludes the accurate prediction of knowledge of loads.

10. The deflections measured on the nine sections of experimental pavement on US 41 at the quarter points in the center of the driving lane for edge loading decreased significantly (in a statistical sense) as subbase thickness increased for the open graded subbase and the 8 inches open graded gave significantly less deflection than the 8 inches dense graded and the untreated subbases.

BIBLIOGRAPHY

(1) Spencer, W. T., "Construction of the U. S. No. 41 Test Road," Purdue University Engineering Bulletin, Road School Proceedings, 1953.

(2) Spencer, W. T.; Allen, Harold; and Smith, P. C., "Report on Pavement Research Project in Indiana," Highway Research Board Bulletin No. 116, pp. 1-56, 1955.

(3) Teller, L. W. and Sutherland, E. C., "The Structural Design of Concrete Pavements," Reprinted from Public Roads, Vol. 16, Nos. 8, 9 and 10, Vol. 17, Nos. 7 and 8 and Vol. 23, No. 8.

(4) "Road Test One - MD," Highway Research Board, Special Report 4, 1952.

(5) Kenney, J. T. Jr., "Steady-State Vibrations of Beam on Elastic Foundation for Moving Load," Paper No. 54-APM-8, The American Society of Mechanical Engineers, 1953.

(6) Hetenyi, M., "Beams on Elastic Foundation," University of Michigan Press, Ann Arbor, Michigan, 1946.

(7) Timosherko, S., "Theory of Plates and Shells," McGraw-Hill Book Company, Inc., N. Y., 1940.

(8) Muskeheliahvili, N. I., "Some Basic Problems of the Mathematical Theory of Elasticity," P. Noordhoff, Groningen, Holland, 1953.

Table 1.

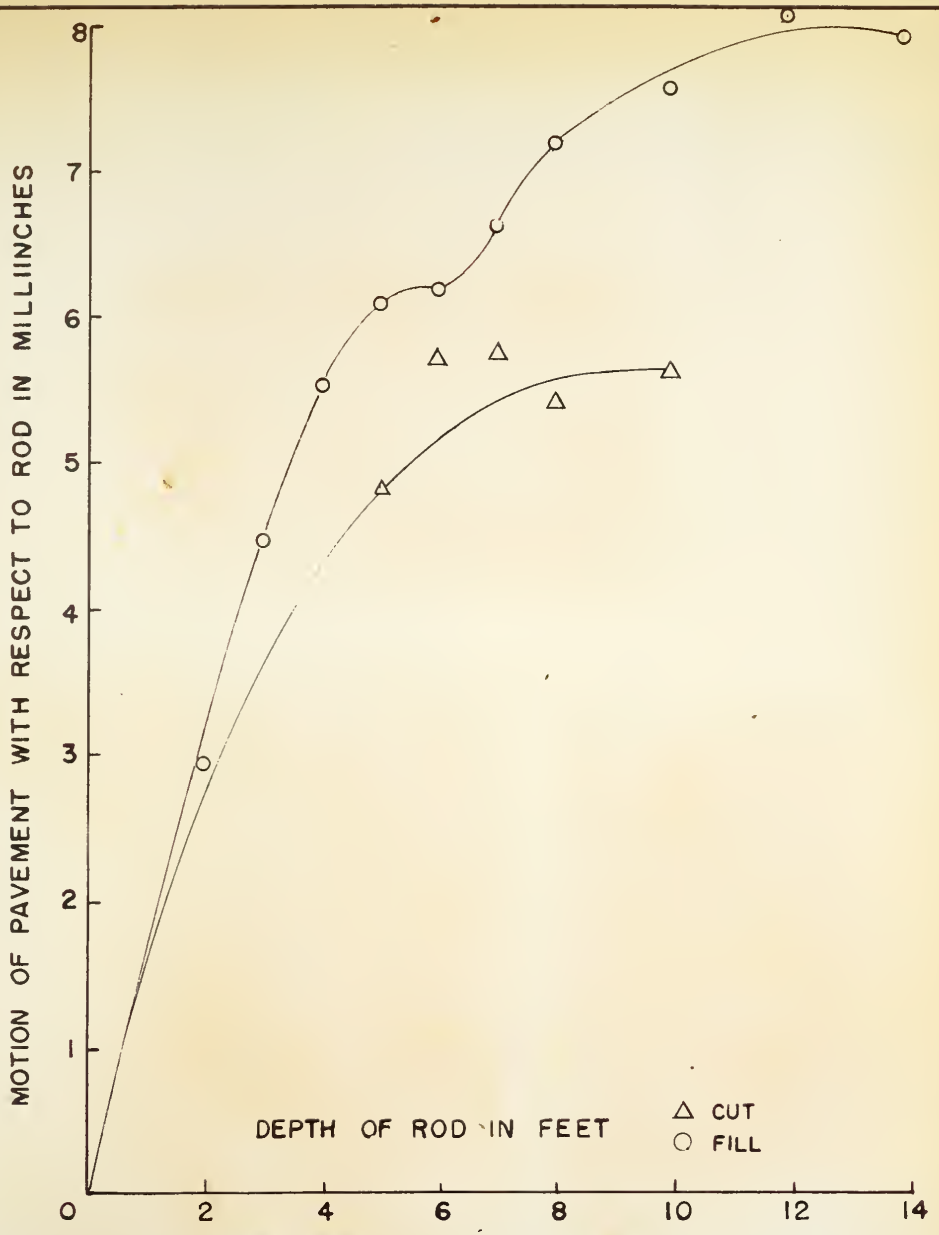
	Truck Weights		
Truck Numbers	103	104	105
Front Axle	8610	8610	8610
Right Front Wheel	4370	4490	4490
Left Front Wheel	4230	4100	4320
	8600	8590	8810
Rear Axle	13620	8610	18910
Right Rear Wheel	7070	4440	9720
Left Rear Wheel	6750	4300	9160
	13820	8740	18880

Scale appears to weigh to about 2%

Figure 1. Brass Sleeve

Figure 2.
Exploded View of Transformer Installation

Figure 3. Calibrator



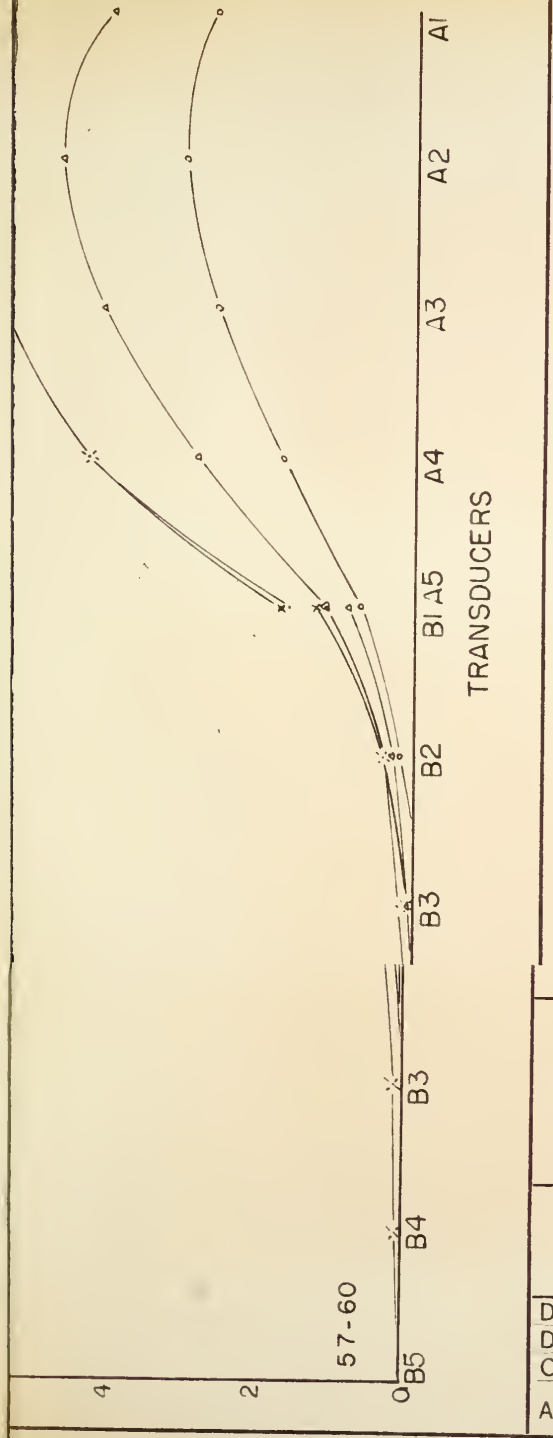
MARK	DESCRIPTION	BY	DATE	APPD
	ALTERATIONS			

ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C 36 A

DEPTH OF LOAD INFLUENCE
SECTION 4B
U.S 41

DESIGNED:	SCALE:
DRAWN: R D S	DATE: 11/7/56
CHECKED: M.E.H.	PD-E-62
APPROVED: RLa	

Figure 4



ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

—·— TRUCK 105_1
—∘— TRUCK 104
—∘— TRUCK 103
—×— TRUCK 105_2

DEFLECTION IN CHART UNITS

ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C 36A

PAVEMENT PROFILES
RUNS 41 - 80

DESIGNED:	SCALE:
DRAWN: S. C.	DATE: 4-10-'56
CHECKED: RLA	PD-E-19
APPROVED: ECG	

Figure 5

PD-E-19

ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

TRUCK 105_1
TRUCK 104
TRUCK 103
TRUCK 105_2

DEFLECTION IN CHART UNITS

DEFL. IN INCHES = CHART UNITS X 0.0015625

REFERENCES

ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C 36A

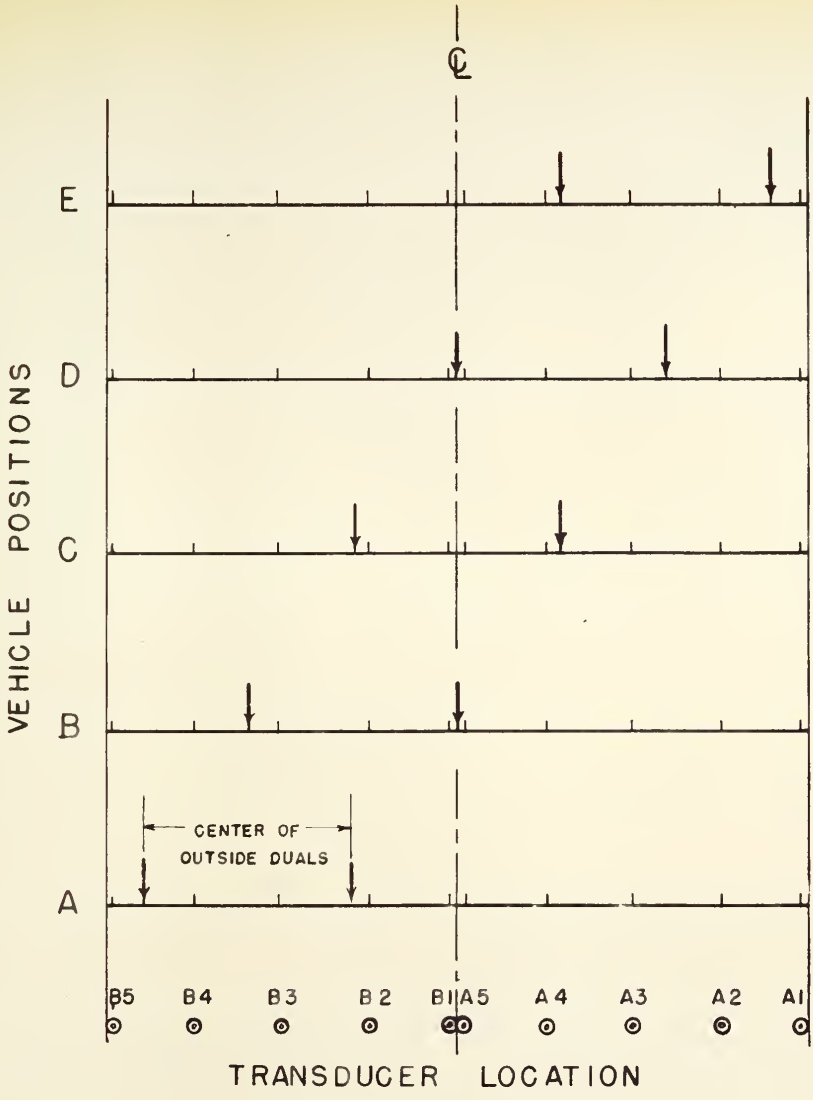
PAVEMENT PROFILES RUNS 41-80

DESIGNED:
DRAWN: S.C.
CHECKED: R.L.A.
APPROVED: E.C.G.

SCALE:
DATE 4-10-56

PD-E-19

Figure 5



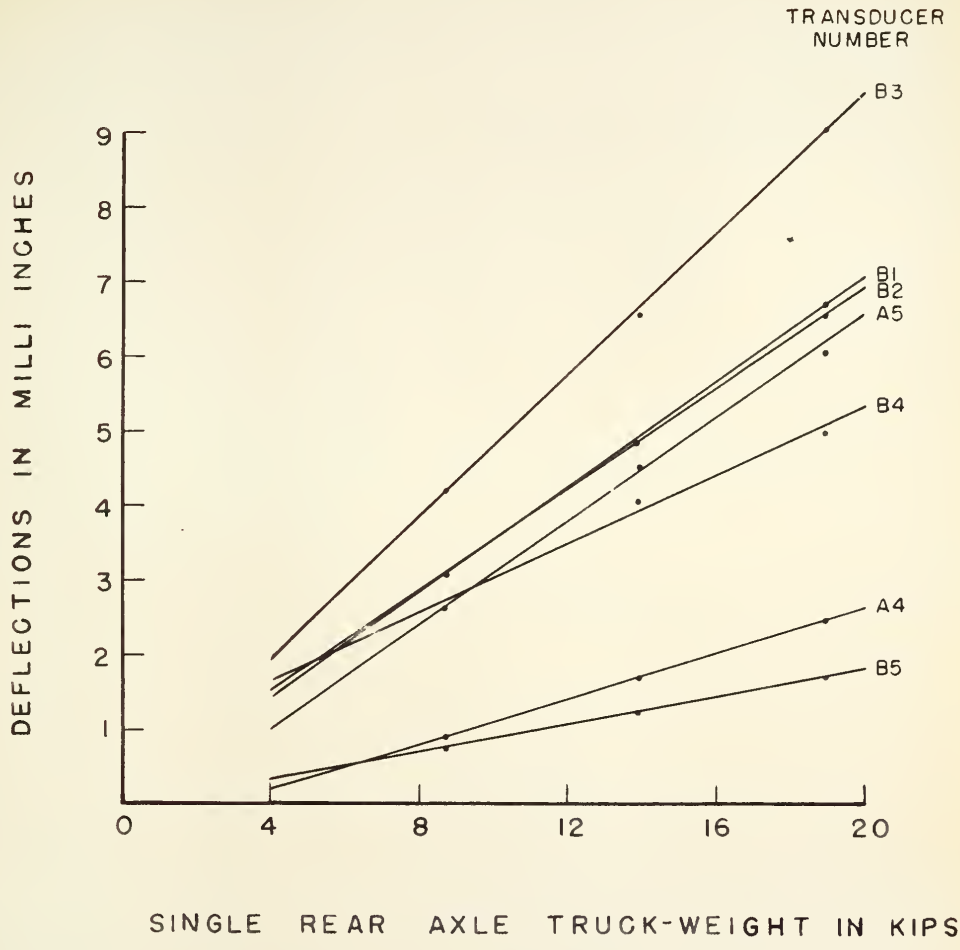
MARK	DESCRIPTION	BY	DATE	APPD
	ALTERATIONS			

ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C 36A

LOCATION OF TRANSDUCERS RELATIVE TO CENTER OF OUTSIDE DUALS OF TRUCKS 103, 104, AND 105 FOR LATERAL POSITIONS A, B, C, D, AND E.

DESIGNED:	SCALE:
DRAWN: P.D.S.	DATE: 6-14-56
CHECKED: A.E.H.	PD-E-25
APPROVED: A.E.H.	

Figure 6



MARK	DESCRIPTION	BY	DATE	APPD

ALTERATIONS

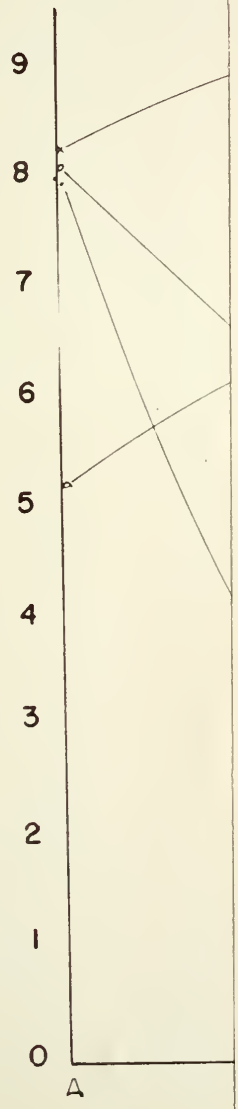
ENGINEERING SCIENCE LABORATORY
PURDUE UNIVERSITY
PROJECT C 36 A

REPRESENTATIVE PAVEMENT DEFLECTIONS
VEHICLE POSITION "B"

DESIGNED:	SCALE:
DRAWN: TFN	DATE: 7-26-56
CHECKED: MEH	PD-E-32
APPROVED: RCG	

Figure 7

PD-E-22



ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

——•——	B-5	A-4
——○——	B-4	A-3
——×——	B-3	A-2
——△——	B-2	A-1

Data from runs 24 through 40

REFERENCES

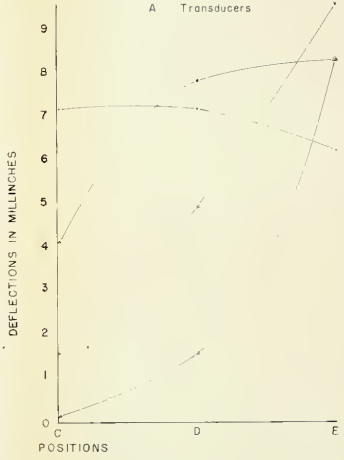
ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C36A

MAXIMUM DEFLECTION AT SELECTED TRANSDUCER POSITIONS VERSUS VEHICLE POSITIONS AT CREEP SPEED.

DESIGNED:	SCALE:
DRAWN: S C	DATE: 5-2-56
CHECKED: RLa	PD-E-22
APPROVED: RLB	

Figure 8

PD-E-22



ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

B-5	A-4
B-4	A-3
B-3	A-2
B-2	A-1

Data from runs 24 through 40

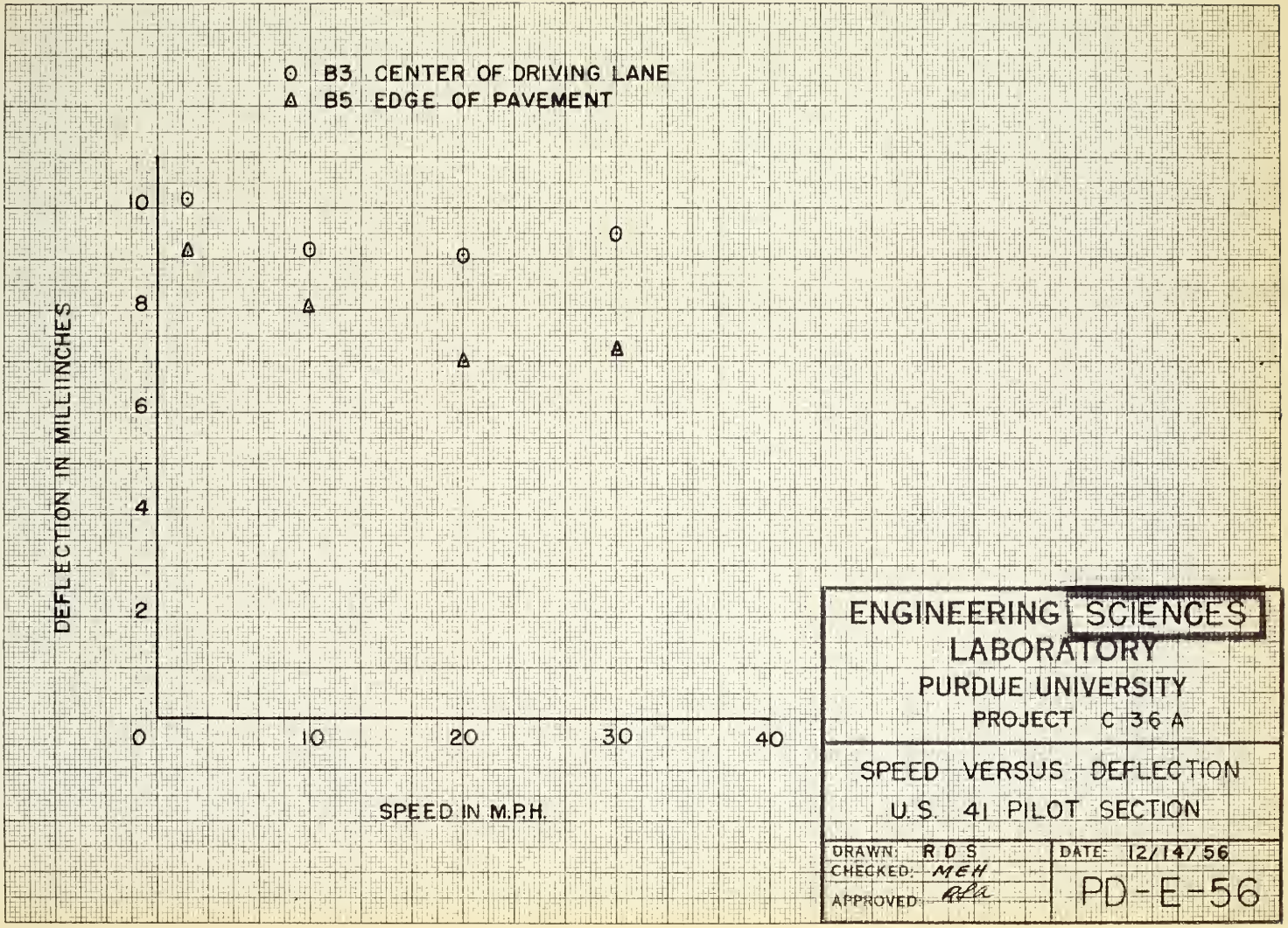
REFERENCES

ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C36A

MAXIMUM DEFLECTION AT SELECTED TRANSDUCER POSITIONS VERSUS VEHICLE POSITIONS AT CREEP SPEED.

DESIGNED:	SCALE:
DRAWN: S.C.	DATE: 5-2-56
CHECKED:	PD-E-22
APPROVED:	

Figure 8

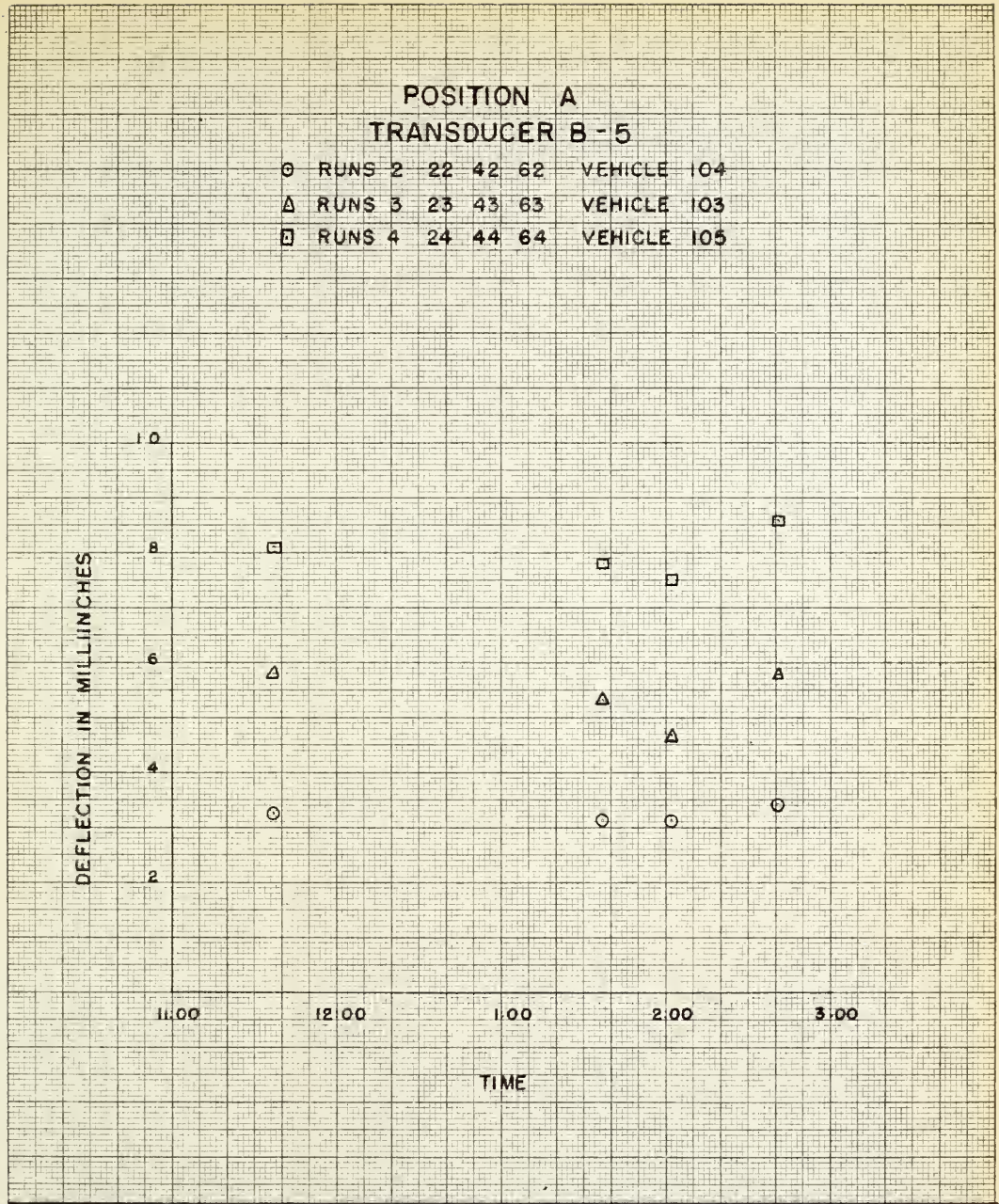


ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C 36 A

SPEED VERSUS DEFLECTION
U.S. 41 PILOT SECTION

DRAWN: R D S	DATE: 12/14/56
CHECKED: MEH	
APPROVED: [illegible]	PD-E-56

Figure 9



PURDUE UNIVERSITY
PROJECT C 36 A

DEFLECTION VERSUS TIME

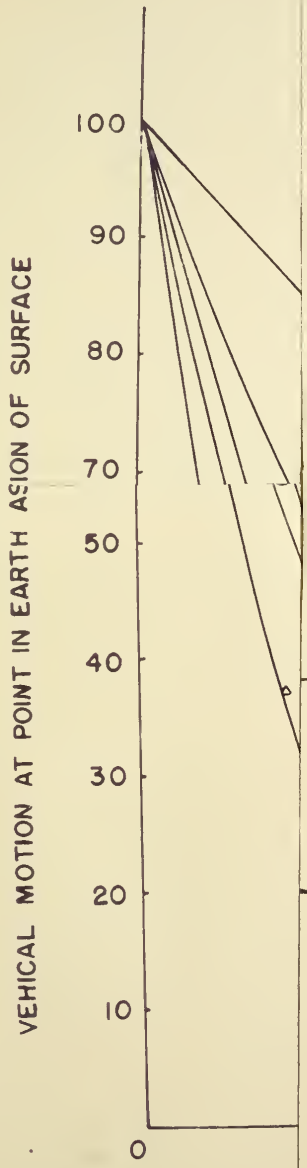
DRAWN: R. D. S.
CHECKED: RLR
APPROVED: CCG

DATE: 23 AUG 1956

PD-E-53

Figure 10

PD-E-59



ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

REFERENCES

ENGINEERING MECHANICS
LABORATORY
PURDUE UNIVERSITY
PROJECT

EARTH MOTION
COMPARISON OF
THEORY WITH EXPERIMENT

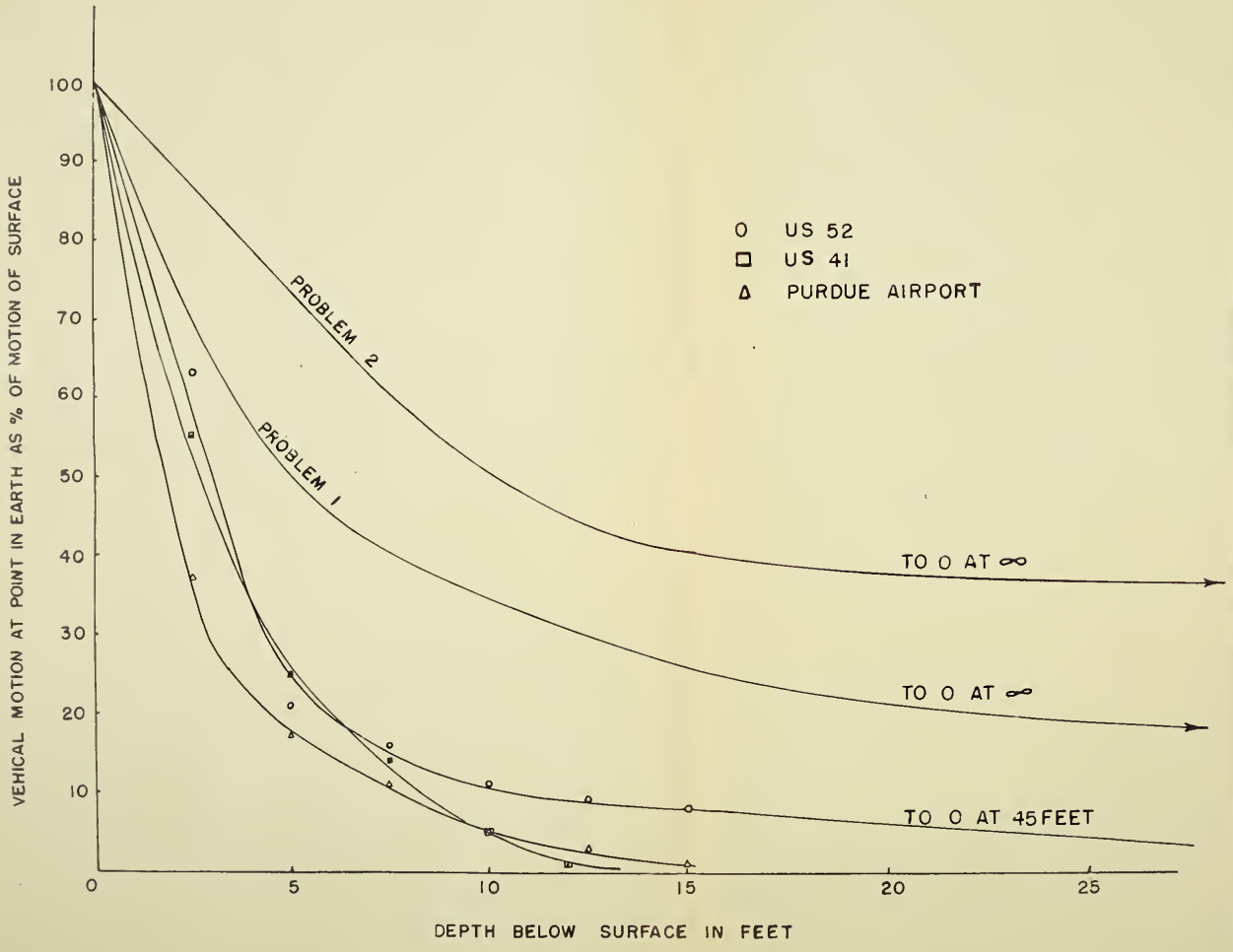
DESIGNED:
DRAWN: R.D.S.
CHECKED:
APPROVED:

SCALE:
DATE:

PD-E-59

Figure 11

PD-E-59



ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

REFERENCES

ENGINEERING MECHANICS LABORATORY
PURDUE UNIVERSITY
PROJECT

EARTH MOTION
COMPARISON OF
THEORY WITH EXPERIMENT

DESIGNED:
DRAWN: R.V.S.
CHECKED:
APPROVED:
SCALE:
DATE:
PD-E-59

Figure 11

ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

o — DEFLECTION GAGE

X — STRAIN GAGE

GAGES DESIGNATED AS INDICATED IN SECTION 4A

524 + 37

518 + 48

ENGINEERING SCIENCES LABORATORY

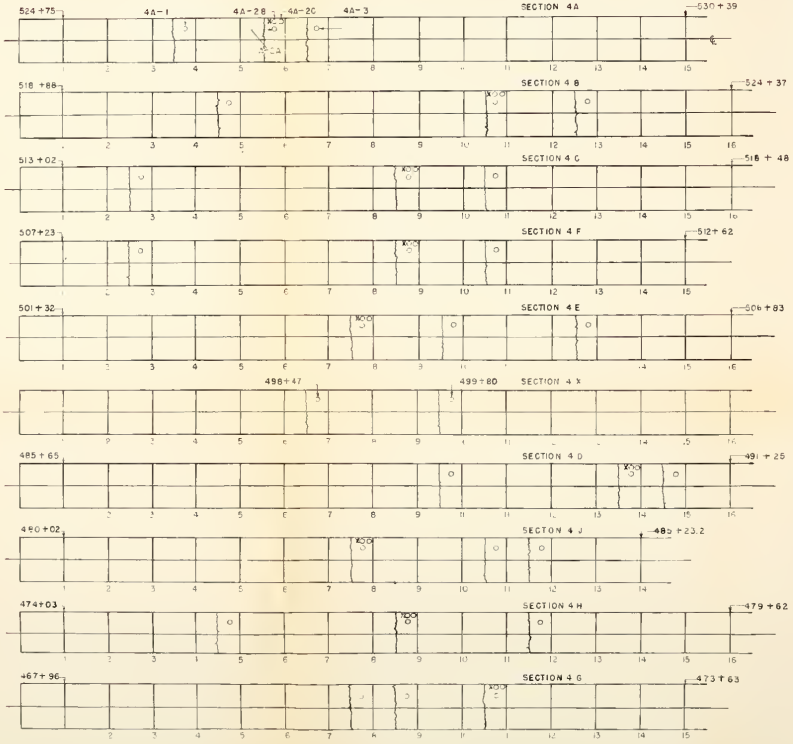
PURDUE UNIVERSITY

PROJECT C 36 A

DESIGNED:	SCALE:
DRAWN: J.A.B.	DATE: 9 AUG 56
CHECKED:	PD-E-43
APPROVED:	

Figure 12

STATIONING OF TRANSDUCER LOCATIONS
U. S. 41 TEST SECTION
SOUTH OF COOK IND.
MARCH 1956



ALTERATIONS

MARK	DESCRIPTION	BY	DATE	APPD

GENERAL NOTES

o — DEFLECTION GAGE
x — STRAIN GAGE
GAGES DESIGNATED AS INDICATED IN SECTION 4A

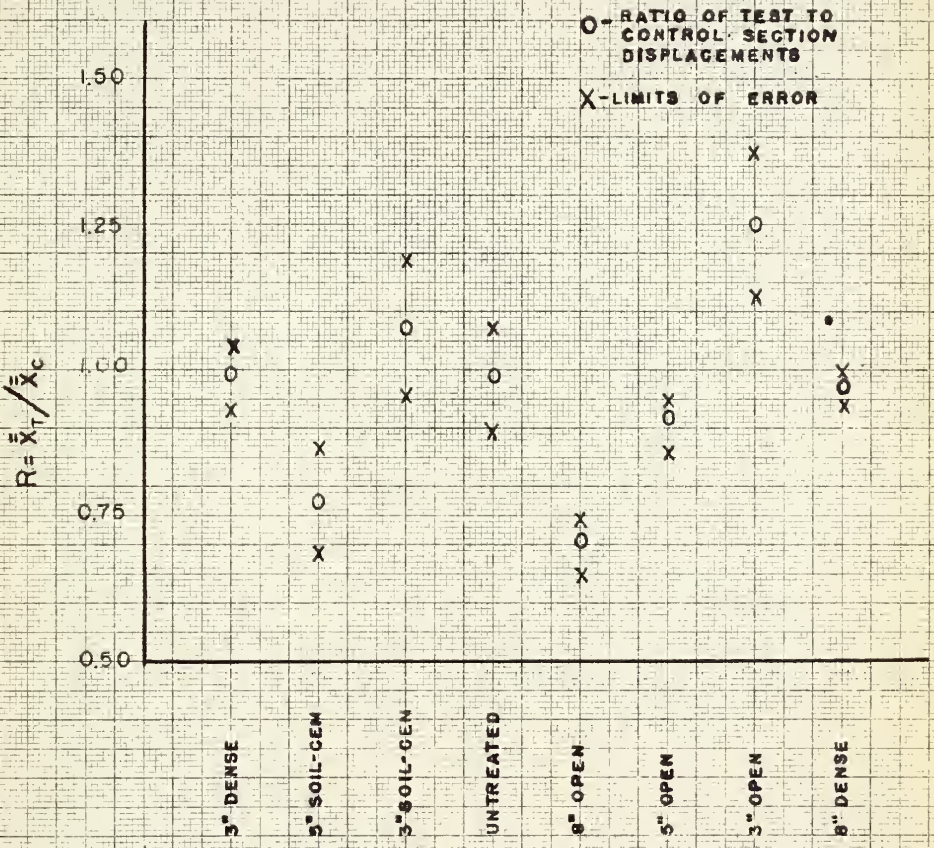
REFERENCES

ENGINEERING SCIENCES LABORATORY
PURDUE UNIVERSITY
PROJECT C 36 A

DESIGNED:
DRAWN: J A B
CHECKED:
APPROVED:
SCALE:
DATE: 9 AUG 56
PD-E-43

Figure 12

VARIANCE IN RATIOS OF TEST TO CONTROL SECTION DISPLACEMENTS FOR QUARTER POINTS, EDGE LOAD



ENGINEERING MECHANICS LABORATORY PURDUE UNIVERSITY PROJECT	DRAWN: CHECKED: APPROVED: DATE:

Figure 13

Table 2.

Section Number	Type Subbase
4A	3" dense graded
4C	8" dense graded
4D	Untreated
4E	3" soil cement
4F	5" soil cement
4G	3" open graded
4H	5" open graded
4J	8" open graded
4B	The control section- 5" dense graded subbase
4X	exception to experiment- fine sand